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Technical Attachment

International Conference on Space Planes and Hypersonic Systems and Technologies

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The American Institute of Aeronautics and Astronautics (AIAA) teamed with their French counterparts, L'Association Aeronautique et Astranautique de France (AAAF), to conduct the 11th AIAA/AAAF International Conference on Space Planes and Hypersonic Systems and Technologies in Orleans, France from September 28 to October 5, 2002. Many may remember President Reagan's State of the Union Address several years ago, during which he advocated aircraft that could fly at hypersonic speed in sub-orbital hops from New York to Tokyo in two hours. These hypersonic aircraft would take off and land as conventional aircraft do. In addition, hypersonic space planes could either reach orbit themselves (single stage to orbit, SSTO) or launch second stages to orbit (two stage to orbit, TSTO). These truly reusable vehicles could replace more expensive expendable rockets. That I participated might cause one to wonder what a meteorologist was doing at the conference? NASA Flight Director Wayne Hale asked me to co-author a paper with him and Nicole Lamotte of United Space Alliance for presentation at the conference. Our paper was titled "Operational Experience With Hypersonic Flight of the Space Shuttle."

Space Shuttle flight experience has highlighted several items of operational impact that should be considered by designers of future space planes. Rocket and space plane builders routinely use standard atmospheres (e.g., 1976 US Standard Atmosphere, GRAM 95, etc.) as a design tool. As most meteorologists are aware, the atmosphere is rarely "standard" and departures from the norm are common. Space Shuttle reentry experience has shown that atmospheric density at great altitudes can vary dramatically. Drag, which is a function of density, has varied by as much as 19% in a few seconds on some Space Shuttle flights at hypersonic speeds. These rapid fluctuations in atmospheric density may have great influence on engine performance, drag, fuel consumption, and flight control for future space planes. Modeling of these "density shears" is very poor in atmospheric standard models. This has resulted in the Space Shuttle carrying a large amount of reserve propellant for its reaction control system for re-entry, and that in turn reduces orbital maneuvering capabilities. Future space planes will likely need to retain these same margins, and that could reduce the amount of payload carried to orbit. In addition, current standard atmospheres poorly model the effects of longitude, latitude and season.

For hypersonic vehicle operators who wish to operate at high latitudes (northward of 50°N) noctilucent clouds may pose a design problem. The Space Shuttle currently avoids re-entry trajectories which fly farther north than 50°N during the noctilucent cloud season around the summer solstice. Originally it was believed that noctilucent cloud nuclei were large enough to damage the thermal protection system of the Space Shuttle, but measurements since the late 1980s have suggested the cloud nuclei are 100 to 1000 times smaller than previously believed. Because of this, Space Shuttle flight design constraints may be changed soon to allow for high latitude re-entry trajectories during the noctilucent cloud season. Air-breathing hypersonic vehicles may still have to consider avoiding the clouds so as not to ingest the particles, but that is a question for engine and aircraft designers to answer. The cloud particles may also increase drag substantially from the standard atmosphere which would also impact vehicle performance and navigation.

Hypersonic vehicles will fly at altitudes where electro-optical phenomena such as red sprites, blue jets, and elves occur. Could the Space Shuttle or a future hypersonic vehicle artificially trigger one of these electro-optical events? The answer is maybe. Meteors have been hypothesized as triggers for red sprites or blue jets. Meteors, and re-entering spacecraft, leave large ionized trails which could trigger some electro-optical discharge. The probability of flying into a red sprite has been estimated by NASA to be very low (about 1 in 100) even over a large thunderstorm cluster. Expert opinion so far is that the electrical environment of these phenomena is *probably* not hazardous to the Space Shuttle. If future measurements show these features could be dangerous then hypersonic vehicles would have to avoid flying over large thunderstorm clusters. These thunderstorm clusters could be hundreds or thousands of miles away from the takeoff and landing site. This could prove to be operationally prohibitive and expensive.

Are hypersonic aircraft and SSTO/TSTO space planes around the corner? We probably will not see them very soon based upon my observations of the conference presentations. The technology is not quite there yet. The ramjet and scramjet engines needed to obtain the required Mach 5 to Mach 15 flight speeds have not yet been flight-tested. Funding needed to get these programs off the ground will require a renewal of national desire and motivation for space exploration and technology. Will hypersonic vehicles ever be built? The answer to that is almost certainly yes. As Boden and Larson (1996) state, input at the early stages of design is critical for reducing future operations costs and safety of space missions. Can meteorology play a role in the design, development, and operation of economic and safe hypersonic flight? The answer is also yes. Meteorologists have valuable insight into the environment in which all aircraft must fly. The FAA is currently licensing spaceports all around the country. Future NWS aviation meteorologists may be issuing forecasts for hypersonic flights to orbit or to Tokyo. TWEB's and TAF's may become more interesting in 15 to 25 years.

Reference:

Boden, D. G. and W. J. Larson, 1996: *Cost Effective Space Mission Operations*. McGraw Hill Inc., 697p.